

# Application Development for Bluetooth Embedded Systems

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## Abstract

Bluetooth is a wireless technology that enables a wireless device to communicate in the 2.4 GHz Industrial, Scientific and Medical (ISM) band. It has been specifically designed as a low cost, low power radio technology, which is particularly suited for the short range Personal Area Network (PAN) application. In this paper we develop an application for a Bluetooth system that will help create a smart billboard that utilizes the individualism of consumer behavior. The essential parts of the development includes the Graphical User Interface (GUI) based application that runs on the mobile devices and the application equipped with advertisement presentation and information exchange capability that reside in the network. The communication between the two major components of the system is based on Bluetooth. The Client Application is targeted to run on a Bluetooth enabled mobile device, e.g. a cell phone. The Server Application is to run on a Bluetooth enabled Intelligent Display Device. Figure 1 describes the working principles of different components of the application.

## 1. Introduction

Wireless Personal Area Network (WPAN) [1] aims to facilitate the communication of devices within a personal operating range of ten meters. It is intended to be a short range, low power and low cost standardization that supports both voice and data communication based on ad hoc topology [1]. IEEE 802.15 Working Group develops WPAN consensus standards for short distance wireless networks. Bluetooth is the open industry specification for short-range RF-based connectivity for portable personal devices. The IEEE Project 802.15.1 has derived a WPAN standard based on the Bluetooth v1.1 Foundation Specifications. Bluetooth is intended to work as data or voice access points, cable replacements or for personal ad hoc connectivity [2].

Bluetooth has emerged as the dominant technology in short range wireless networks. As

Bluetooth is steadily gaining popularity as time progresses, the importance of application development of Bluetooth is becoming apparent [3]. In this paper an application for Bluetooth embedded system is developed while addressing some core requirements of software engineering processes. The developed application intends to create a smart billboard that utilizes the individualism of consumer behavior. The essential parts of the development includes the Graphical User Interface (GUI) based application that runs on the mobile devices and the application equipped with advertisement presentation and information exchange capability that reside in the network. The communication between the two major components of the system is based on Bluetooth. The Client Application is targeted to run on a Bluetooth enabled mobile device, e.g. a cell phone. The Server Application is to run on a Bluetooth enabled Intelligent Display Device. Figure 1 describes the working principles of different components of the application.

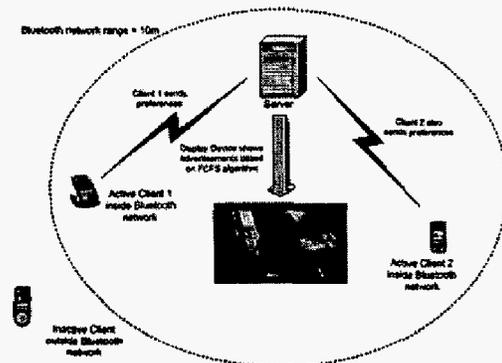


Figure 1: Principles of the Application

This is how the rest of the paper is organized. Section two has an overview of Bluetooth, section three illustrates the developed application, section four describes the development tools, section five explains

the communication networks, section six describes the functionalities of the developed application and section seven concludes this paper.

## 2. Bluetooth Overview

### 2.1 Bluetooth Technology

Bluetooth is a short range, low cost and low power wireless communication standard. It overcomes the limitations of Line of Sight and One-to-One communication of its possible competitor Infra-Red (IR). Bluetooth operates in the 2.4 GHz Industrial, Scientific and Medical (ISM) band at a maximum data rate of 720 Kbps [1]. It uses Frequency Hopping Spread Spectrum [1] that divides the frequency band yielding 79 channels. The modulation used is a Gaussian-shaped binary Frequency Shift Keying (GFSK) modulation scheme. Very low cost non-coherent FM receivers can be used for reception. It supports both voice and data oriented communication. Voice oriented service request is handled by a complex negotiation process to ensure Quality of Service (QoS). Data oriented service request is handled by Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). It has provision for both symmetric and asymmetric data transmission [4]. Figure 2 describes the Bluetooth Protocol Stack.

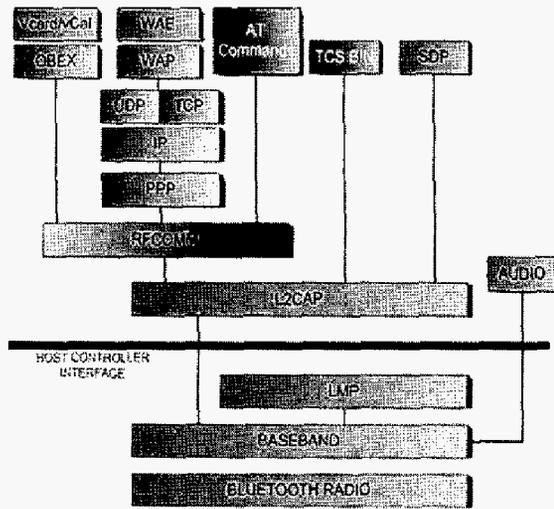


Figure 2: Bluetooth Protocol Stack

### 2.2 Bluetooth Network Formations

The elementary Bluetooth network, termed as the Piconet, is an ad hoc connection between at least two devices [5] as shown in Figure 3. The connection initiator is a master and others are slaves. In most of the cases, the connections are point to point. Masters can have simultaneous connections with seven slaves. When a device is connected to two or more Piconet, it is known as the Scatternet [5] as shown in figure 3.

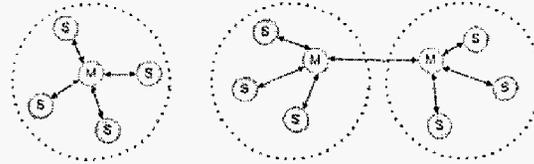


Figure 3: Piconet (left) and Scatternet (right)

### 2.3 Bluetooth Application Domains

Bluetooth has three broad categories of application domain as described next.

**2.3.1 Voice/Data Access Points.** Bluetooth enabled devices can work as voice/data access points and can connect computing devices to communicating devices via a secure wireless network. It may help share Internet connection with another mobile device. Bluetooth may be used as public access points as well. Bluetooth enabled mobile devices may use the Internet while within ten meters of the public access points [6].

**2.3.2 Peripheral Interconnects.** The second category of application, peripheral interconnects, involves connecting multiple devices. All the peripheral devices of a computer might be connected to the PC over a wireless link reducing cost and wire-hazards. If equipped with the proper application, Bluetooth can also be used for proximity security devices where two devices need to be within ten meters of each other to get into the security system [6].

**2.3.3 Personal Area Network.** Personal Area Network may vary from product searching in a super market to personalized advertisement system. Whenever two Bluetooth enabled devices are within ten meters, they can share many resources. Using that attribute, applications that might provide some simple but very effective value added service to the user of the Bluetooth enabled devices can be developed [6].

### 3. The Developed Application

The application is engineered through a prototype development process model. It falls into the third category of application domain for Bluetooth described in section two. It can be considered as a third party software application that takes advantage of pre-qualified Bluetooth features of a product through the Application Programming Interface (API). The application does not incorporate new protocol or profile functionality. Usually new Bluetooth protocols or profiles are only possible for the manufacturer of the product. As it is not the case, the development is on the Bluetooth Stack and intends to use the existing resources to create an interactive application that is capable of addressing some real-life market needs.

The application is developed in a client-server model. The proper implementation requires both the components though they might work independently. The client application assists the user to select their personal preference, i.e. the things they are most likely to buy. The Server Application looks for the client application within ten meters. If it finds one, it gets the preferences from the client and shows advertisement accordingly.

#### 3.1 The Client Application

The client application is designed to run on a cell phone that has Bluetooth embedded in it. The application was developed for a standard platform, Symbian Operating System [7]. Figure 4 illustrates the portion of Symbian Stack that the client application uses.

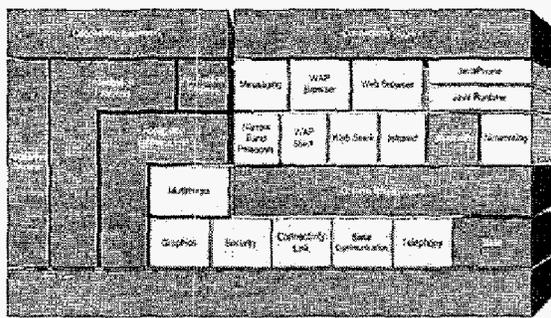


Figure 4: The Client Application's utilization of Symbian OS Stack

The desired program contains some consumer preferences which can be entered and modified by the

user(s). The Client Application provides a simple, easy-to-use combo-box type user interface where the user is capable of selecting up to three preferences. Whenever this Mobile device comes within ten meters of the server, it sends the preference information to the server application. The communication is automatically initiated whenever the Client comes within ten meters of the Server.

#### 3.2 The Server Application

The server application runs on a Bluetooth Enabled Intelligent Advertisement System. The application resides in a Stationary System, i.e. an electronic advertisement system or a PC and operates on a standard operating system like Linux.

Figure 5 shows the interfacing of a Bluetooth device with an Intelligent Advertisement System and how the Server Application is interconnected with different layers of the host system. The desired program contains some preinstalled advertisement in the database that can be entered and modified by the administrator(s).

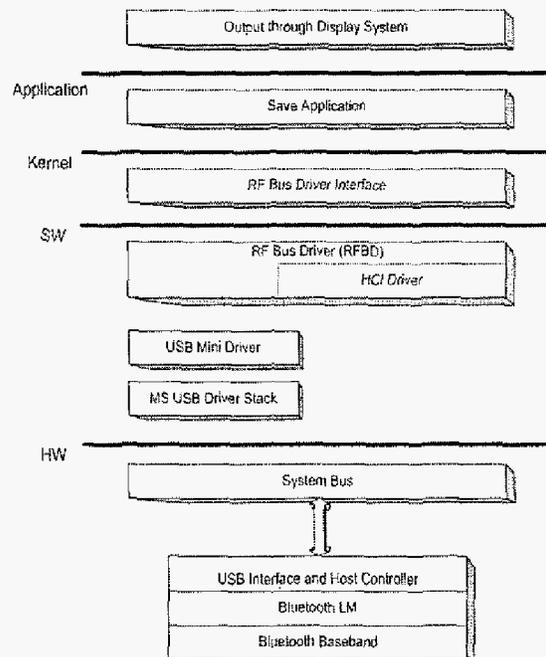


Figure 5: The Server Application's interconnection with the Host

Whenever a mobile device comes within the communication range of the server, it receives the preference information from the mobile device and

performs a search through the database. Then the server decides its action on the basis of received data from the client and the search result and shows the advertisements on the electronic billboard accordingly. The communication is one way; from the client to the server. The response of the server is not directly to the client. Rather it responds through the display system that operates on the instructions given from the server. At the initial level, the application runs in a PC. But for practical purposes, the application would be put within an electronic control box that would allow the application to actually show the advertisements through some other electronic display system.

## 4. Development Tools

### 4.1 Development and Testing Hardware

The hardware devices should address three issues: a Graphical User Interface (GUI) based interactive process at the client end, a Bluetooth based communication between the client and the server and the presentation of advertisement through some display system at the server end.

At the client side, the hardware should be a mobile device that operates on some standard platform like Symbian OS, has Bluetooth radio built in and provides possibilities of application development on that device. The device should also be physically available for testing and development process and widely used in the market. The development team selected Nokia 7650 for that purpose as it meets all the criteria. Selection of this particular cell phone is also influenced by the availability of Software Development Kit (SDK) for the platform through the Internet without any cost during the time of the development.

At the server side of the application, necessities include a machine that is capable of holding and processing a data base, capable of hosting the server application and sending instructions to the display system. At the initial level, due to availability and ease of implementation, the server machine is selected to be a Personal Computer (PC).

For communication between the client and the server device, Bluetooth radio should be available at both the components. The client device has Bluetooth radio embedded in it. But for the server device, physical Bluetooth adapter that enables Bluetooth communication from and to the server machine is also essential. The Bluetooth adapter or dongle interfaces with the PC via Universal Serial Bus (USB) port and

implements the part of the protocol stack that is obligatory for communication of the client and the server side of the application.

## 4.2 Development Environment

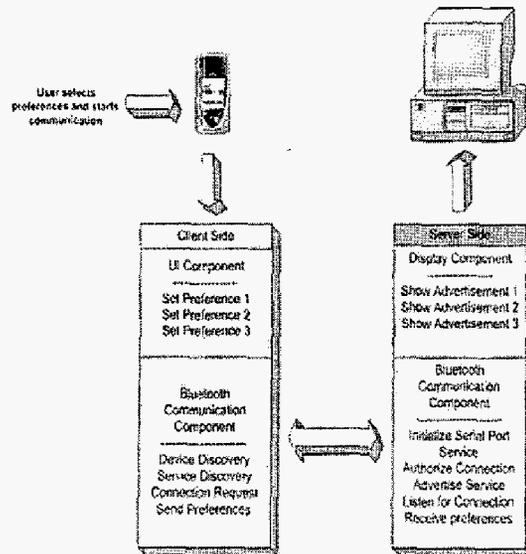
**4.2.1 Client Application.** Nokia 7650 is categorized as a Series 60 mobile device with a software platform designed for hand operated *smartphones* with a large color screen and an intuitive User Interface (UI). The platform supports a variety of development choices including C++, Java and WML. As the application is intended to be platform independent, Java comes as an obvious choice. The difficulty was the unavailability of the APIs that enables the application to communicate over Bluetooth. The Reference Implementation of the Bluetooth API for J2ME was unavailable. As a result, the choice was shifted to C++ as Nokia provides all the APIs to use its networking features including Bluetooth in their SDK. Though the application development is a bit more cumbersome and time consuming, the development team had to rely on C++ for the development of the client side application [8].

**4.2.2 Server Application.** The server application should be able to communicate with and receive data from the client application. The Server Side development platform chosen was Linux because it has a free Bluetooth stack, BlueZ [9] that helps in the development of the server application. It should also be noted that Windows platform also has Bluetooth stacks but development using those stacks require purchasing SDKs from the manufacturers.

Application development using the BlueZ stack requires using the JBueZ API [9]. JBueZ is a Java package which interfaces with the BlueZ Bluetooth protocol stack for Linux, providing a simple means in which to add Bluetooth functionality to Java applications. It is designed to bring open source Bluetooth support to J2SE and J2EE without any reliance on proprietary third-party protocol stacks.

## 5. Communication and Network

As the application is based on a client-server model, there is a network component involved. The communication between the client and the server is based on Bluetooth.



**Figure 6: Communication Network of the Application**

As described in section three, the server would declare an ad hoc network within the ten meter range and declare itself as the master. Whenever a client device moves within the range, it would try to establish an active connection with the server and be a slave. This can be done without any active action from the user. Considering the possible deployment strategy of the application, the network topology would be a simple Piconet.

Figure 6 elaborates the different steps in communication between the server and client application and the network formation.

## 6. Functionalities of the Application

The functionalities of the client application are quite different from the server one. Even then, combined together, they are a complete system as the server application depends on the information from the client application running in mobile devices and the client application remains idle until and unless paired with a server application. When the client and server program come within ten meters of each other, the network is formed and the communication begins as elaborated in section five. When the necessary information is sent to the server program, then the actual functionalities and their implications for both the application becomes apparent.

## 6.1 Client Application

The Client application runs on top of Nokia 7650. A complete and point-and-click based operating system Symbian controls the functionalities and operations of the device. Just like the desktop of any GUI of an operating system for a PC, it has an icon based menu. The user can use the joystick to browse through the icons and select the appropriate icon. The client application is represented as an icon named BTBD499 on the menu. When the user selects the icon, the client program is launched. Then, the user will be presented with three options from which he/she can select his/her preference. When the user intends to select a particular choice, it would take his/her to another combo-box type menu from which the user can select the preference from a predefined list. The user cannot select second or third preference unless the previous one is already selected. The user has several options among which clearing and saving the choices are important ones. If the user intends to do it, he/she can simply select the appropriate option. Figure 7 shows how the GUI is used to save user preferences in the client application.

## 6.2 Server Application

The server application responds via a display device. It runs on a Bluetooth enabled intelligent advertisement system. This application carries a database that holds a pool of advertisement. When the user selects the preferences, it is saved as an encoded preference string. Whenever any mobile device that has the client application running appears within ten meters of the server the preference string is automatically sent to the server. The server decodes the string and finds the preferences. Then it searches through the database and looks for the appropriate advertisement. Then the server instructs the display system to show the advertisements. The user is allowed to choose up to three preferences. The advertisements are shown in the order of preference. The ads are rotated until the user moves away from the range of the network or another user enters the network. If there are multiple requests, it operates on the "first-come-first serve" basis. Refer to figure 1 to get an overview of the combined functionality of the applications. Figure 8 displays a sample advertisement displayed through the server application.

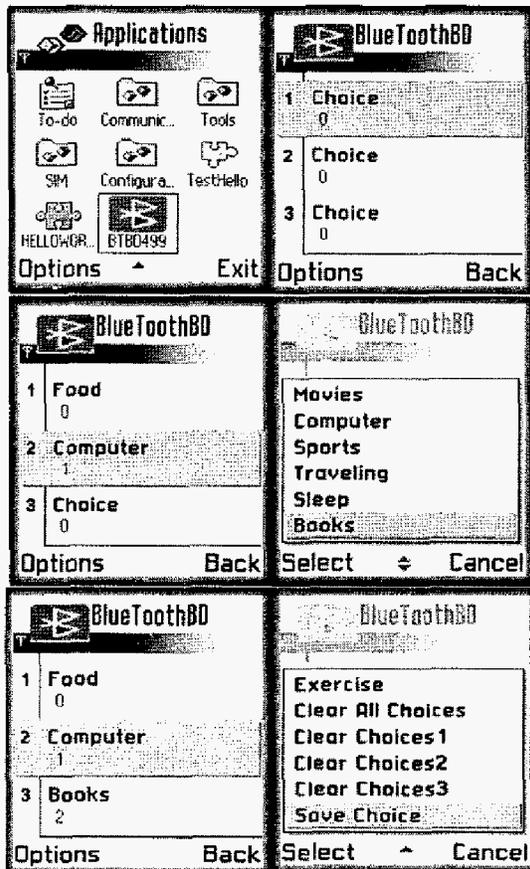


Figure 7: The Graphical User Interface at the Client Application

## 7. Conclusion and Future Work

In this paper we have successfully developed a Bluetooth based smart billboard. Very similar application might be developed for this application domain (section 2.3) that would have very high demand in terms of consumer requirements. Not only those, other domains demand high quality applications as well. Very similar application can be developed to guide cell phone holders to the right direction in airports or big departmental stores according to their destination or necessity. Electronic appliances having Bluetooth support at home or office can be adjusted according to personal preferences. These applications would be just some minor readjustment of the developed application at least in terms of the Client side and the communication part. The developed application however has some room for expansion. The client side of the application may include a

Bluetooth API that would interpret the service request from the client directly and react accordingly.

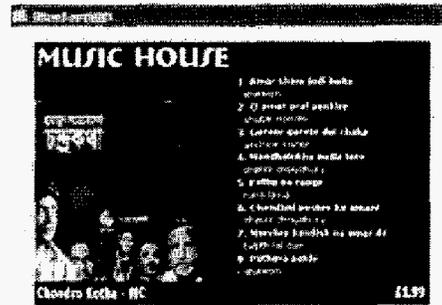


Figure 8: The Advertisement from the Server

## Acknowledgement

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